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RESEARCH PAPER

Sustainability of native maize family farms in Mexico: Current trends from a socio-agronomic perspective

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Abstract

The sustainability of family farms, or Family Production Units (FPUs), cultivating native maize varieties in Chiapas, Mexico, is intricately linked to economic, socio-productive, environmental, and cultural factors. Given their significance within the regional socio-productive framework, the objective of this study was to assess sustainability across environmental, social, and economic dimensions. The methodology employed for sustainability analysis was the Framework for Evaluation of Natural Resource Management Systems (MESMIS). Thirty FPUs were purposively selected from 14 communities spanning four municipalities and were typologically classified into three groups: Traditional, Maize Growers-Livestockers, and Diversified. In-depth interviews were conducted with individual farmers, complemented by group interviews involving entire families. The collected data underwent processing through multiple correspondence statistical analysis, analysis of variance for linear models, and multiple comparisons of means. The results indicated that the Diversified FPU group exhibited higher sustainability, covering 68% of the sustainability perimeter. Consequently, this group demonstrated better conditions for preserving native maize varieties over time and developing strategies to meet their needs concurrently. The Traditional FPU group covered 58%, while the Maize Growers-Livestockers group covered 52% of the sustainability perimeter. In conclusion, it was observed that family reproduction strategies, grounded in resource utilization (capitals), shape forms of nature appropriation that are continually reconfigured. These configurations play a pivotal role in defining the sustainability of FPUs engaged in native maize cultivation in the Frailesca region.

Keywords

Family production units, Family reproduction strategies, Frailesca region, native maize varieties, Sustainability

Introduction

In recent decades, the assessment of the sustainability of socio-agricultural systems has become an increasingly prevalent and imperative subject, given the global impact of contemporary production models. Misconceptions associating food scarcity solely with production constraints, rather than distribution issues, have spurred the intensification of agro-productive processes under the guise of Rural Modernization. This approach has, in turn, contributed to the overexploitation and degradation of natural resources (Bellon et al. 2009). Primarily oriented toward the production of raw materials rather than food, this model has engendered environmental challenges, jeopardizing the sustainability of traditional agroecosystems and exacerbating inequality in rural areas (Easdale et al. 2018).

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In this agro-environmental framework, it is asserted that the relationship between society and nature is rooted in the human appropriation of the environment to fulfill essential needs for survival and biological as well as social reproduction. Agro-productive processes leave an indelible mark on this relationship, shaping socio-cultural patterns over time that significantly impact the sustainability of Family Production Units (FPUs) (Toledo 2008; Barrios-García et al. 2020). Sustainability, conceived as the enduring stability of an agroecosystem over time, relies on the harmonious (co)evolution of society and nature. It also encompasses the system's ability to self-regulate and adapt to ensure continued food production, economic prosperity, social well-being, and the preservation of natural and cultural resources without compromising its functionality (Gutiérrez-Cedillo et al. 2008; Masera et al. 2008).

According to Salazar-Barrientos and Magaña-Magaña (2016), maize holds strategic significance for Mexican Family Production Units. In line with their criteria, this crop serves as the cornerstone of both sustenance and the economy for many rural families, carrying immense cultural value. Consequently, the organization and functionality of FPUs in rural regions, such as Frailesca, are intricately linked to maize cultivation. This connection is vital not only for ensuring food security but also for implementing local strategies of social reproduction, wherein native maize assumes a fundamental role (Guevara-Hernández 2007). As such, the sustainability of FPUs significantly hinges on their capacity to judiciously employ, manage, and conserve native maize varieties within their agroecosystem over time (Arias-Yero et al. 2023).

According to Hellin and Bellon (2007), in 2005, the cultivation of native maize varieties in the Frailesca region experienced a 60% decrease in the planted area and a 10% decrease in the number of farmers engaged in this activity. This declining trend persisted in 2011, as reported by Guevara et al. (2011), who observed that only 14.3% of farmers continued to plant native maize varieties in the region. Over the past two decades, evident degradation of the natural resource base, including soil, water, and vegetation, has occurred in this region. This degradation is attributed to the prevailing production model that aims to increase crop productivity and profitability (Martínez-Aguilar et al. 2020a). Additionally, factors such as climate change, migratory phenomena, neoliberal policies, and the pursuit of more lucrative activities exert a direct and continuous impact on Family Production Units. However, native maize, distinguished by agronomic and economic characteristics differing from commercial hybrids, remains a crucial component of the region's sociocultural fabric, with the identification of at least 88 cultivars in recent studies (Guevara-Hernández et al. 2020; Guevara-Hernández and Mariaca-Méndez 2023).

Numerous studies have delved into two distinct aspects: the richness and conservation of native maize varieties (Bellon et al. 2006; Perales 2009; Guevara-Hernández et al. 2019a, 2021; Hernández-Ramos et al. 2020), and concurrently, the sustainability of the maize agroecosystem (Aguilar-Jiménez et al. 2011; Martínez-Aguilar et al. 2020b). However, in this region of the country, no evidence has been found of studies examining the sustainability of family units that actively preserve native maize.

This research scrutinized the sustainability of FPUs engaged in the cultivation of native maize varieties, encompassing environmental, social, and economic dimensions. The study facilitated a more comprehensive understanding of the dynamics surrounding native maize and, particularly, the perspectives regarding its utilization, management, and conservation within FPUs, adopting a holistic sustainability approach. To achieve this, three distinct types of FPUs were previously identified, classified based on the characteristics of their human, social, physical, natural, and financial-productive capitals: Traditional, Maize Growers-Livestockers, and Diversified.

Materials and methods

The study was conducted in four municipalities of the Frailesca region in Chiapas, Mexico: Villaflores, Villa Corzo, Ángel Albino Corzo, and Montecristo de Guerrero (Fig. 1). This region is characterized by its predominantly agricultural activities and is situated between the coastal plain of the Pacific Ocean and the central depression of Chiapas. The primary economic activities include maize cultivation (with an average yield of 3.5 t ha^{-1}), coffee production, and livestock farming (SIAP 2019, 2020). Thirty-five percent of the population resides in rural areas marked by a high degree of social marginalization. Of this population, 95.45% are of mixed ethnicity, while only 4.55% are of indigenous origin (Gobierno del Estado 2014).

Methodology

To explore sustainability, the study utilized theoretical frameworks on social reproduction (Bourdieu 2011) and rural metabolism (Toledo 2008). The investigation involved the comparison of different Family Production Unit groups, with methodological support from the Framework for Evaluation of Natural Resource Management Systems ["Marco para la Evaluación de Sistemas de Manejo de recursos naturales incorporando Indicadores de Sustentabilidad" (MESMIS)]. This framework assessed the sustainability level of FPUs by categorizing them into groups relative to each other (Astier et al. 2008). The following steps were undertaken:

Determination of the study object

As part of a previous investigation, three groups of FPUs were identified—Traditional, Maize Growers-Livestockers, and Diversified FPUs (Arias-Yero et al. 2022). For this purpose, 30 FPUs were randomly selected from 14 communities across the four municipalities (Table 1).

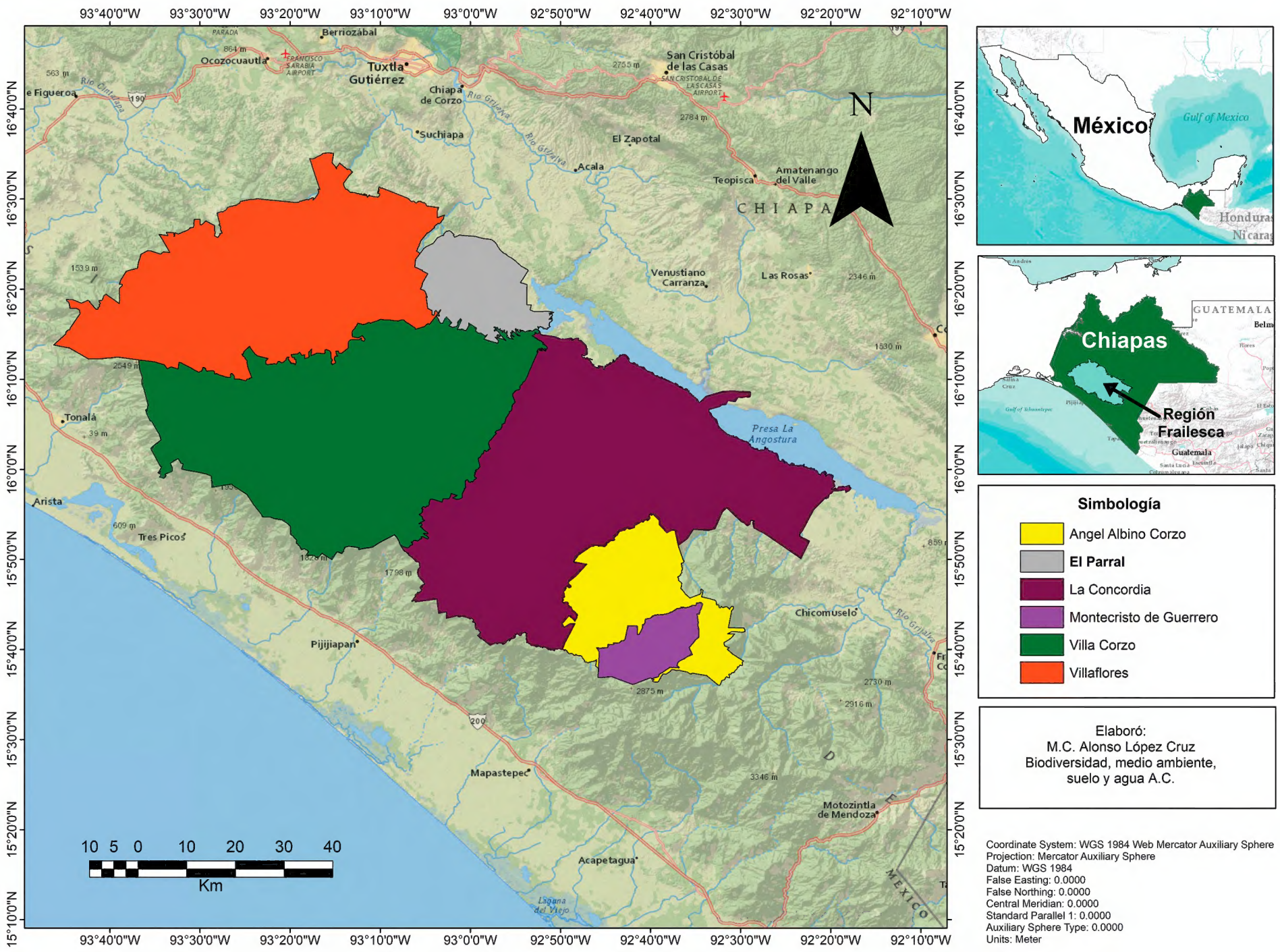

Figure 1. Location of the municipalities of Frailesca, Chiapas (Mexico). Source: Own elaboration.

Table 1. Types of FPUs and their distribution across communities and municipalities in the Frailesca region, Chiapas, Mexico.

Group/characteristics	Municipality	Community/No. FPU
GI: Traditional FPUs, are more specialized in agricultural work, with a high profile towards coffee cultivation. They are more attached to traditional management practices and have less human, financial, and physical capital.	Ángel Albino Corzo	Chiquinillal/2 Libertad el Pajal/3
	Villaflores	Los Ángeles/1
	Montecristo de Guerrero	San Nicolás/2
GII: Maize growers-livestockers FPUs, have high levels of capitalization, articulate native maize cultivation with livestock and their management practices are more modern with more use of agrochemicals.	Ángel Albino Corzo	Jaltenango/1
	Villaflores	Roblada Grande/2 Guadalupe Victoria/1 Jesús M. Garza/1 Benito Juárez/1
	Villa Corzo	Monterrey/1
GIII: Diversified FPUs, is the most representative. They show medium levels of capitalization and have achieved greater diversification of both agricultural and non-agricultural activities. In this case, the children tend to conserve the cultivation of native maize.	Villaflores	Benito Juárez/2 Roblada Grande/2 Guadalupe Victoria/3
	Villa Corzo	Villa Corzo/1 Valle Morelos/3 Buena Vista/2
	Ángel Albino Corzo	Francisco I. Madero/2

Source: Arias-Yero et al. (2022).

Subsequently, sampling was conducted for unknown populations, such as the universe of FPUs cultivating native maize in the Frailesca region, using the following formula:

$$n = (ZxS/e)^2$$

Here; Z = 1.96 representing a 95% confidence level; S = denotes the standard deviation derived from the prior exploratory study, and e = is set at 5%, representing the sampling error employed in the analysis.

Identification of critical points

The critical points arose from the characteristics of the FPU that influence or contribute to sustainability, including strengths and weaknesses. In roundtable discussions involving farmers, family members, ejido commissioners, teachers, officials from the Centro de Apoyo para el Desarrollo Rural (CADER) [Support Center for Rural Development], and seed company sales promoters, several characteristics were deliberated, integrated, and distilled into nine critical points (Table 2).

Measurement and monitoring of indicators

Direct measurements were conducted in the field through multiple visits to farmers and their families. We conducted in-depth individual interviews with farmers and group interviews with entire families. These sessions thoroughly

Table 2. Indicators evaluated for the analysis of the sustainability of native maize FPUs in Frailesca, Chiapas (Mexico).

Attribute	Critical point	Indicators	Unit of measure or category
Equity and generational continuity	Generational continuity (S)	Family involvement	Number of persons
		Historical preservation of LC	Number of years
		Continuity of children	Number of children
		Migration to cities	Number of migrants
Self-management	Capital stock (S)	Local relations	Good, fair, bad
		Participation in networks	Yes, No
		Institutional relations	Good, fair, bad
Self-management	Dependence on external resources	Labor force dependence	High, medium, low
		Agrochemical dependence	Ratio of agrochemical costs to total costs
		Dependence on government support	Level of dependence
Stability, resilience, and reliability	Diversity and food self-sufficiency (A, S)	Varieties of LC	Quantity
		Associated crops	Quantity, species
		Food dependence LC subsystem	High, medium, low
		Family self-sufficiency with LC	Number of months
		Cultural value of native maize	Perceptions
Adaptability, Stability, resilience, and reliability	Traditional knowledge (S)	Agroecological practices	Minimal or zero tillage, use of stubble as fertilizer, stubble for direct cattle grazing in the field, burning, etc.
		Type of planting	Manual, Mechanized, Both
		Use of native seeds	Frequency of use
Productivity	Profitability (E)	Yield	t/h
		Production costs	Mexican pesos
		Benefit/cost ratio	U
		Contribution to the family economy	Number of months
Adaptability, Stability, resilience, and reliability	Pluriactivity (S)	Specialization in activities	Agricultural, Non-agricultural, Both
	Water (A)	Sources of access to water	Natural, Constructed, Neither
		Adaptation to climate change	Type of adaptation
		Effects of adaptation	Disease risk, total crop loss, no bean intercropping, none, other
Self-management	Physical capital (E)	Ownership of transportation	Yes, No. Consequences
		Ownership of machinery	Yes, No. Consequences
		Road quality	Good, Regular, Bad. Consequences

Note: Native maize (LC), Environmental dimension (A), Economic dimension (E), Social dimension (S).
Selection of sustainability indicators: We identified 29 quantitative and qualitative indicators based on critical points, with a particular focus on social indicators (Speelman et al. 2008).

analyzed the current conditions of selected indicators and gathered perspectives on them.

Presentation and integration of results

For ease of comparison across FPUs, indicators were standardized on a scale of 1 to 10, irrespective of their nature, using an extrapolation procedure. In this procedure, 10 represented the optimal value closest to sustainability, while 1 indicated the furthest point from it (Astier et al. 2008; Blandi et al. 2015). The optimal values were determined based on the maximum mean values obtained in the study and were integrated into an "amoeba" type graph.

Statistical analysis

Statistica software version 8.0 for statistical analysis was employed. Quantitative variables underwent an analysis of variance for linear models, evaluating variable behavior by groups. The Duncan test facilitated multiple comparisons of means. Additionally, multiple correspondence factor analyses were performed, associating groups with variables grouped by critical points and sustainability attributes according to MESMIS (Astier et al. 2008)

Results and discussion

Equity and generational continuity

The longevity of an FPU demonstrates its capacity to sustain activities across generations, thereby significantly contributing to its overall sustainability. Among the FPUs, the Diversified group exhibits the most favorable conditions for achieving this, supported by an average of 1.7 men engaged in native maize cultivation. This FPU has preserved this maize type for approximately 50 years, uniquely maintaining an average of one son involved in the activity even after becoming independent from the FPU. The behavior observed in the Diversified group can be attributed to economic considerations. These families inherit what Bourdieu (1979) terms a "value of scarcity," lacking the economic means to support the education of all their children. Consequently, while some members pursue education, others remain linked to the family's productive tradition.

In contrast, the Maize Growers-Livestockers FPUs, with higher levels of capitalization, adopts a different educational strategy aimed at preventing their children from

continuing the cultural heritage linked to maize cultivation, deeming it "hard and ungrateful." Educational strategies become social investment strategies when the goal is for children to pursue education and attain higher status in society, irrespective of the continuity of the family's cultural heritage. Thus, family ethical strategies do not prioritize the subordination of children to the agricultural tradition, as referenced by Bourdieu (2002), but rather the family aligns itself with and supports the aspirations of its children.

Concerning the continuity of children in native maize cultivation, the Maize Growers-Livestockers FPUs, following Bourdieu (2011), aim for the transmission of material inheritance across different generations, excluding the transmission of immaterial heritage (the tradition of preserving native maize). In other words, land inheritance is no longer perceived as a cultural process, where the duty to continue the agricultural tradition is considered more important than the right to property itself, as suggested by Arias-Yero et al. (2023) and Guevara-Hernández (2007). This shift has resulted in an increased migratory flow to urban areas and the reconfiguration of the FPU towards alternative activities in pursuit of aspirations and achievements unrelated to rural life. Although more noticeable in the GII, according to Guevara et al. (2020), this phenomenon seems to be gradually becoming more widespread among families cultivating native maize in the Frailesca region.

A distinct sexual division of labor prevails in 100% of the FPUs. Men from the generation of the family head, who serve as both workers and administrators, directly participate in the cultivation of native maize. Women play a crucial role in supporting the productive process through domestic activities, ensuring the well-being, cleanliness, etc., of the men working in the fields and their young children. Although women's work is often practically invisible, the products obtained from the backyard, such as vegetables and poultry, contribute to the income and food security of the FPU. The GI exhibits lower family participation (1.3 on average) due to the higher number of children under 5 years of age.

Social capital

Migratory patterns and shifts in family activities have enhanced the FPU's ability to manage human capital by employing labor and leveraging local connections. Traditional (GI) and Diversified (GIII) FPUs cultivate robust social capital, particularly in terms of neighborhood ties. These groups exhibit informal local collaborations in maize cultivation, such as "el cambio de mano" (hand-exchange) and "el invitadito" (invitation), where farmers support each other without financial compensation, contributing to lower production costs through reduced contracting. However, the widespread use of shelling machines has streamlined and expedited work, affecting these forms of local collaboration.

Formal collaborative networks remain marginal, posing a constraint on sustainability. According to Díaz-José et al. (2018), fostering cooperation among farmers yields shared benefits in the long term. The GI, with a strong focus on coffee production, actively participates in coffee cooperative organizations. In terms of institutional relationships, the GII stands out for engaging in productive advisory and experimental projects with university institutions (UNAM, UNACH, etc.), "Productores Asociados de Semillas" (PROASE) [Seed farmers' association], and "Modernización Sostenible de la Agricultura Tradicional" (MasAgro) [Conservation Agriculture Program]. Similar findings were reported by Maza and Sarandón (2015) in Tucumán, Argentina, where well-capitalized bell pepper farmers established more effective connections and experimentation with institutions.

Dependence on external resources

All FPUs manage labor, agrochemicals, and governmental support external to the FPU. In this context, Vázquez-González et al. (2018) argue that importing external inputs does not contribute to sustainability as it increases dependence on exogenous resources, limiting autonomy.

FPUs require varying degrees of hired labor for their operations. Maize growers-livestockers, cultivating 1.61 ha, demand more hired labor than Traditional (0.91 ha) and Diversified (1.46 ha). According to Toledo (2013), in the process of nature appropriation, FPUs must employ additional labor when the farm size exceeds their biological and technological capacities.

Concerning fertilizer use, an economic rationale is evident, with better-capitalized FPUs such as Maize growers-livestockers and Diversified having more frequent access to combinations with Diammonium Phosphate (DAP) and Urea, priced between $ 500 and 700 MX pesos, respectively. Traditional FPUs, with fewer resources, rely more on Ammonium Sulfate, priced around $ 290 to $ 300 MX pesos in 2020, as reported by Pizaña-Vidal et al. (2019) in the municipalities of Villa Corzo and Villaflores. Despite these variations, all groups extensively use agrochemicals, constituting 43% of total expenditures in GI, 57% in GII, and 47% in GIII.

Increased use of agrochemicals correlates with greater soil resource deterioration (Orozco-Hernández et al. 2017). Consequently, the more harm inflicted on natural resources, the greater the future effort required by the FPU to appropriate them (Toledo 2008). In other words, each production cycle demands more fertilizer to enhance soil productivity. Simultaneously, input prices witness an annual increase, estimated at approximately 10%, as reported by farmers and sales managers.

Governmental support is another factor marking the dependence of Traditional and Diversified FPUs on external resources, whereas Maize growers-livestockers exhibit more autonomy. The latter possess better conditions to cover the production costs of native maize from their endogenous resources (income from hybrid maize, livestock, and non-agricultural activities). Similar findings were reported by Uzcanga-Pérez et al. (2020) in groups of rainfed maize farmers in Campeche.

Diversity and food self-sufficiency

Agrodiversity was assessed based on the number of conserved varieties and associated crops. The GI conserves a single native variety, aligning with the findings of Guevara-Hernández et al. (2020), while the Maize growers-livestockers and Diversified groups conserve an average of two varieties. A higher number of varieties reduces the risk of losing local genotypes and increases the likelihood of the emergence of new ones. Consequently, this mitigates the potential for future agronomic catastrophes, such as the loss of these varieties and self-sufficiency in maize seed management within the FPU (Cuevas-Coeto et al. 2019).

Contrary to the predominant monoculture observed in the maize system in Frailesca (Martínez-Aguilar 2020b), the study reveals that in crops featuring native maize, associations with at least one additional crop are more common (Fig. 2). Traditional FPUs exhibit higher agrodiversity, with squash being a common element across all. To a lesser extent, *Canavalia* sp. and other beans are also present, primarily designated for self-consumption due to farmers deeming them unprofitable. In regions like Tlaxcala, the polyculture system demonstrates greater species diversity, with 94.9% of farmers incorporating some variety of legume that enhances soil chemical composition (Sánchez-Morales and Romero-Arenas 2018; Aguilar-Jiménez et al. 2019).

Traditional FPUs allocate 53% of their production for family self-supply. However, Maize growers-livestockers only consume 8%, and the Diversified group consumes 22%, figures lower than those reported in the States of Mexico, Tlaxcala, and Guerrero (López-Torres et al. 2017).

Self-sufficiency encompasses both human and animal food, as indicated by Guevara-Hernández et al. (2019b) in the Sepultura Biosphere Reserve. This is based on the estimated average of 335.8 kg of maize consumed per year by Mexicans (SIAP 2020). The Traditional FPU exhibits better food self-sufficiency from native maize, while the Maize growers-livestockers are less sustainable in terms of the role of native maize in their family diets (see Table 3). Consequently, maize consumption during the remainder of the year is supplemented with hybrids produced within the FPU, as well as flour and industrialized tortillas.

Table 3. Family self-supply from native maize in FPUs in Frailesca, Chiapas (Mexico).

Type of FPU	Self-supply (kg)	Human consumption (kg)	Food self-sufficiency (months of the year)
GI: Traditional	900	170	6.1
GII: Maize growers-livestockers	400	59	2.2
GIII: Diversified	960	163	5.9

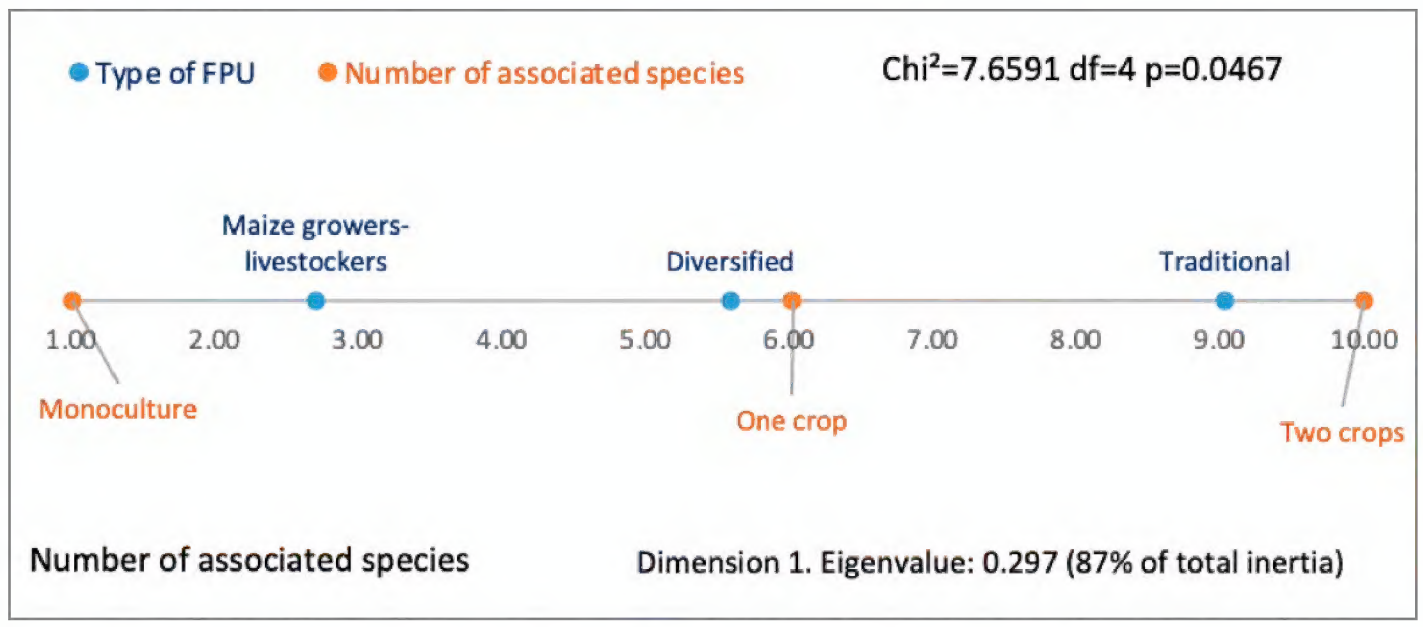

Figure 2. Types of FPUs and number of species associated with native maize in Frailesca.

All FPUs exhibit a low level of food self-sufficiency based on the native maize subsystem. According to Toledo (2008), their sustainability and social reproduction no longer rely solely on the exchange with nature and its resources but also on relationships within the social environment. The Traditional group (GI) demonstrates higher autonomy (Fig. 3) as they engage in associations with beans, another significant component of the region's diet. Additionally, by utilizing fewer agrochemicals, they rely more on wildlife resources, even though this form of nature appropriation (Toledo 2013) is gradually diminishing in the region. In both the Maize growers-livestockers (GII) and Traditional (GI) FPUs, pumpkins predominate, primarily destined for seed sales and not directly contributing to the family's diet.

The earlier generations place emphasis on the cultural and culinary significance of native maize, but the subsequent generations, comprising children and grandchildren, fail to discern significant distinctions between the different types of maize. Nevertheless, all generations consume hybrid maize and its processed products due to their cost-effectiveness. This indicates a shift in the population's dietary preferences, prioritizing economic considerations over cultural ones (Fletes-Ocón et al. 2014). Food traditions associated with native maize, viewed by Bourdieu (1979) as a component of personal cultural capital, appear to wane and vanish with an average generation age of 59 in a region where life expectancy at birth is 75.2 years (Picazzo-Palencia et al. 2018). The diminishing use value of native maize, particularly pronounced

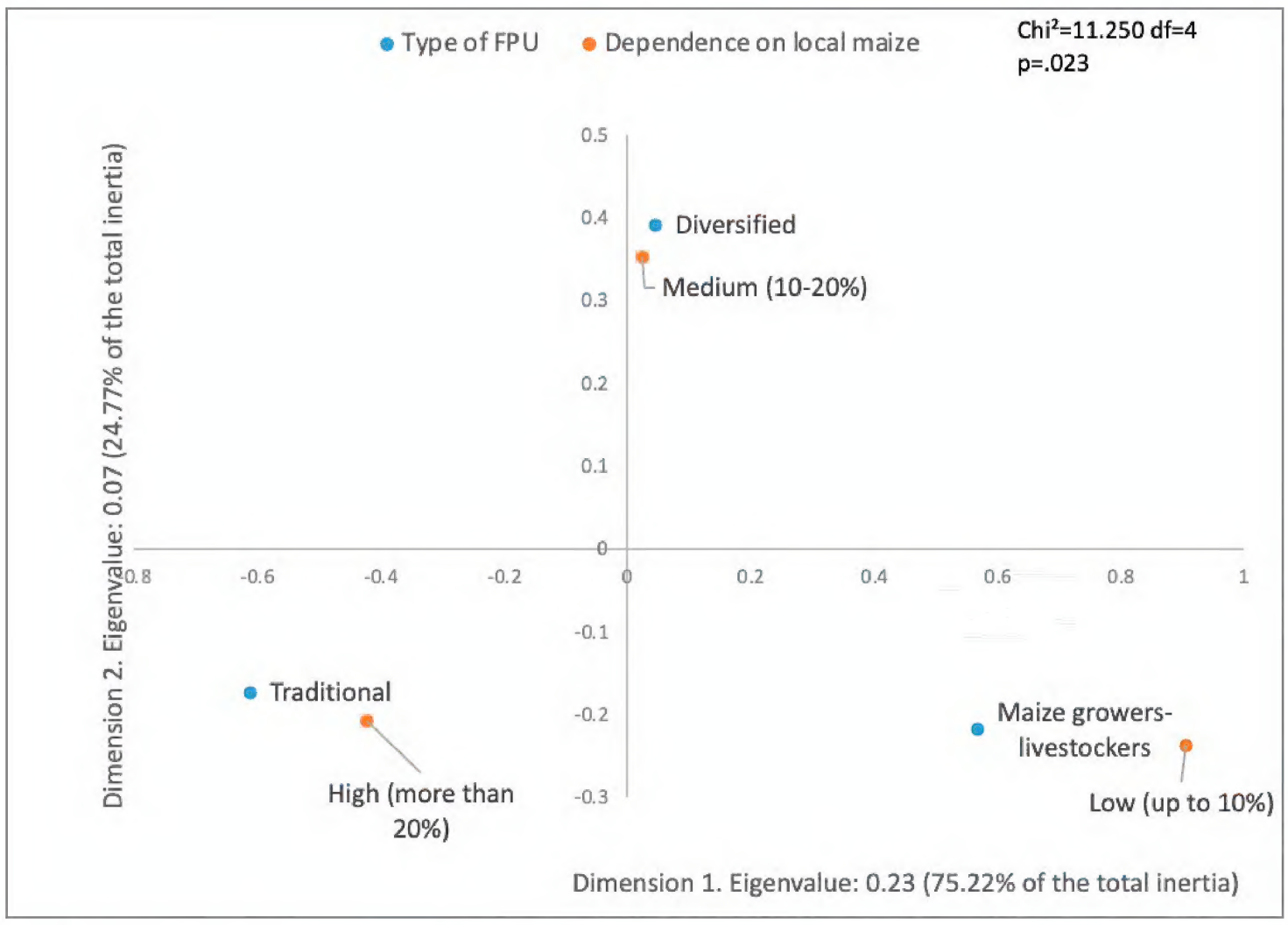

Figure 3. Levels of food dependence of the native maize subsystem in the Frailesca FPUs.

among the Maize growers-livestockers, is a phenomenon that further jeopardizes its conservation in the medium and long term.

Traditional knowledge and agroecological practices

In the regional maize FPUs, manual planting and minimum or zero tillage practices generally prevail, aligning with the practices of farmers in the Soconusco region (Fletes-Ocón et al. 2014). This observation is supported by Sánchez-Gómez et al. (2021), who acknowledge a low rate of machinery adoption among maize farmers in Chiapas. However, in Frailesca, this trend doesn't entirely manifest as a conscious soil conservation effort. According to Guevara et al. (2018b), a substantial portion of plots (66% in this study) exhibits stony and sloping characteristics, making them less suitable for mechanization. Moreover, the influence of native maize extensions and the limited financial capital within most FPUs play a role. Only the more financially endowed Maize growers-livestockers FPUs, primarily situated in flat areas, integrate both manual and mechanized planting methods.

In FPUs GI, stubble serves as fertilizer, whereas in GII, it is utilized directly as cattle feed in the field. In GIII, which introduces limited cattle (mostly leasing land to cattle farmers), the stubble is burned before planting. Retaining stubble in the field is conducive to sustained soil conservation. However, the introduction of livestock without proper care can lead to soil compaction (Guevara et al. 2018b). Conversely, Martínez-Aguilar et al. (2020b) found that none of the studied groups identified crop rotation, indicating a lack of intention to implement conservation practices, in conjunction with other factors. In terms of the utilization of native seeds, GI employs 32%, GII uses 21%, and GIII relies on 52%, percentages that are lower than the 65% reported for the use of native seeds in Chiapas overall (SIAP 2019). Furthermore, in specific regions of the state, such as Comitán, the usage of native maize seeds is even higher at 79% (Fletes-Ocón 2017). The remaining seeds cultivated in these groups are hybrids, aligning with the findings of Delgado-Ruiz et al. (2018), who describe this as a family strategy emphasizing the complementary functions between native and hybrid maize, with hybrids being more predominant. Farmers corroborate what Cadena-Íñiguez (2004) asserted two decades ago in the Frailesca, linking the conservation of native maize primarily to the high cost of hybrid seeds and the associated cost savings.

The preservation of native seeds within the diversified FPU is also intertwined with cultural factors. Firstly, the farmers, with an average age of 62, exhibit a strong affinity for native maize. Secondly, there is a higher proportion of the native population (albeit in a minimal percentage), which demonstrates a more profound cultural connection with these maize cultivars. Economic considerations introduce a dynamic element to conservation, mirroring the fluctuations in the market. As per farmers' perspectives, a decrease in the price of hybrid seeds may lead to an increased adoption rate, given their superior yield (3.44 t ha^{-1} for hybrids compared to 2.67 t ha^{-1} for natives) and resistance to lodging. Conversely, the ongoing escalation in seed prices, which were quoted around $3,200 MX pesos in the region in 2020, suggests a potential inclination to revert to native varieties. Consequently, diversified farmers, who cultivate native seeds for both economic and cultural reasons, attain greater stability in the conservation of these maize varieties. Overall, fully traditional

or agroecological practices were not entirely identified; instead, akin to the situations in Puebla and Yucatán, a knowledge dialogue is predominant (López-González et al. 2018; Vázquez-González et al. 2018). However, GII exhibits lower sustainability compared to the other groups, as it tends to align more with the modern paradigm, incorporating environmentally unsustainable practices (Martínez-Aguilar et al. 2020b).

Profitability

FPU Maize growers-livestockers and Diversified farmers achieved the highest yields in native maize, as shown in Table 3, which is a positive factor for sustainability. However, this increased yield is attributed to higher investments in agrochemicals, aligning with findings from Guevara-Hernández et al. (2018b) and Martínez-Aguilar (2020b). These studies label such practices as unsustainable due to their adverse effects on family economies, natural resources, and an increased reliance on external resources. Consequently, Maize growers-livestockers and Diversified farmers are deemed less sustainable than their Traditional counterparts.

The cultivation of native maize proves to be a lucrative venture for the studied FPUs, with a benefit/cost ratio exceeding $ 1.00 Mexican peso, consistent with the findings of Sánchez-Morales and Romero-Arenas (2018) in Tlaxcala. In contrast, Traditional FPU registers the lowest index in this indicator (Table 3) due to factors such as cultivated area, production destination, and sales prices. With only 47% of their production reaching the market, Traditional FPUs have a smaller market share compared to Maize growers-livestockers and Diversified FPUs, which stand at 92% and 78%, respectively, impacting their overall family economy.

Geographically, Maize growers-livestockers and Diversified FPUs have better access to "Seguridad Alimentaria Mexicana" (SEGALMEX) warehouses, a Mexican food security program, compared to the Traditional group. The guaranteed prices in these warehouses, set at $5,610 MX pesos per ton and expected to increase to $6,060 in 2022 by the "Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación" (SADER) [Ministry of Agriculture, Livestock, Rural development, and Fishing], contribute significantly to a higher benefit/cost ratio than reported by Guevara-Hernández et al. (2018a). Consequently, the monthly expenditures reported by Maize growers-livestockers and Diversified FPUs have a more substantial impact on the family economy (Table 3). Traditional FPUs, on the other hand, contribute to food and cultural aspects.

Table 4. Profitability of native maize cultivation and impact on the family economy in Frailesca, Chiapas, Mexico.

Indicator	Traditional	Maize growers-livestockers	Diversified
Yields (t ha^{-1})	1.8	3.1	3
Total production (t)	1.69	4.99	4.38
Marketed (t)	0.79	4.59	3.42
Sales price per ton (MX pesos)	4550	4641	4600
Total income (MX pesos)	3595	21302	15732
Total production costs (MX Pesos)	3569	12337	9353
Profit/cost ratio	1.01	1.69	1.68
Monthly family expenses (MX pesos)	2685	5243	4400
Impact on family economy (months per year)	0	1.7	1.4

Pluriactivity

While native maize cultivation proves to be a profitable activity, with FPUs, on average, recovering the cost of their investment, it falls significantly short of ensuring the social reproduction of the family. This underscores the necessity to engage in additional economic activities that complement family strategies, confirming the inherently pluriactive character of the situation.

All the surveyed FPUs exhibit some degree of pluriactivity, reflecting a lifestyle that inadvertently contributes to the conservation of native maize. Maize growers-livestockers and the Diversified group, driven by a

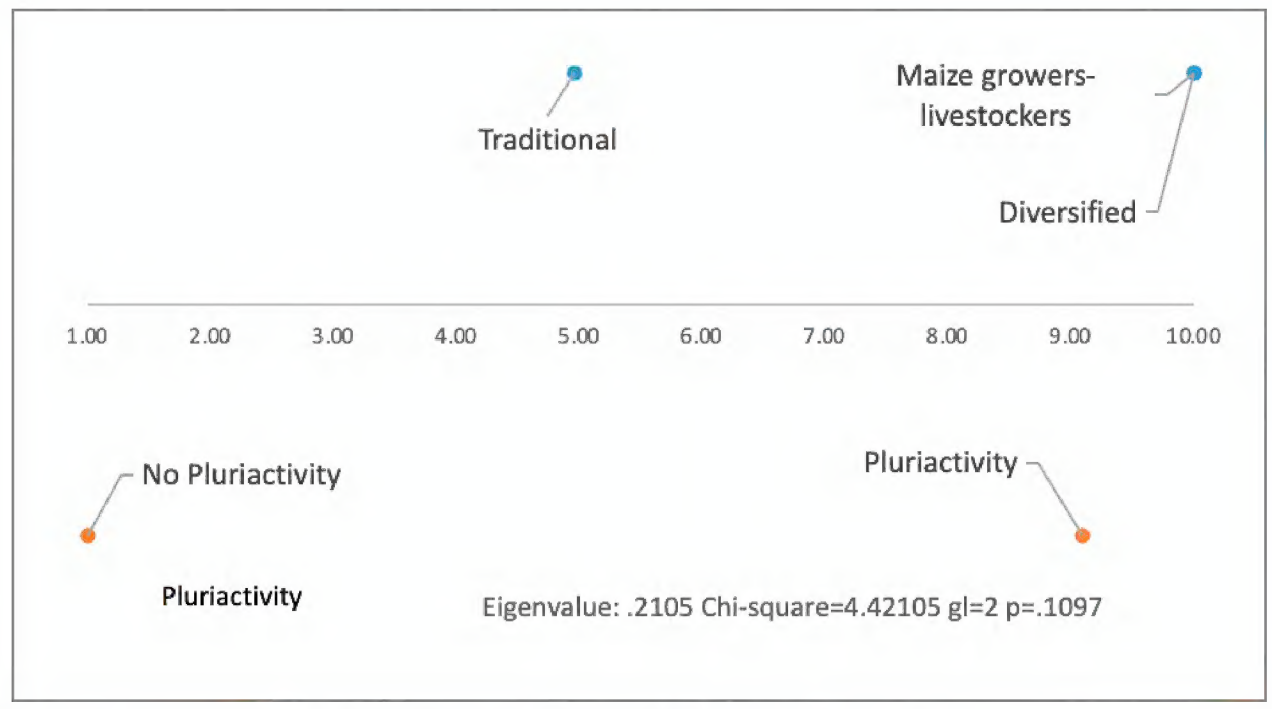

Figure 4. Scale of pluriactivity in the native maize FPUs in the Frailesca region.

desire to enhance their working and living conditions, engage in various agricultural and non-agricultural activities, including the commercialization of labor, groceries, livestock, and maize products. In contrast, Traditional farmers specialize more in agricultural pursuits, primarily focusing on coffee as their main source of income.

According to Toledo (2008), diversifying activities provides greater resilience to uncertainties and natural surprises, along with increased flexibility and adaptability to economic risks, while specialization diminishes resilience to various changes. Hence, in this context, Maize growers-livestockers and Diversified farmers demonstrate greater sustainability compared to their Traditional counterparts.

Water

Resilience plays a crucial role in ensuring the sustainability of native maize FPUs in Frailesca, given the inherent risks posed by climate change, particularly in rainfed agriculture. Farmers, apart from GII, lack access to water resources, relying on natural springs and artisanal water wells ("norias"). The variability and intensity of rainfall have necessitated a shift in the commencement of the production cycle. A noteworthy 95% of the interviewed farmers plant in June and July, aligning with practices observed in the state of Campeche (Uzcanga-Pérez et al. 2020). Consequently, native maize becomes more susceptible to diseases such as asphalt spot. Both Traditional and Maize growers-livestockers FPUs express concerns about the heightened risk of losing a portion or the entirety of their harvest due to the delayed start of the production cycle. This delay has also impacted the bean crop, with farmers acknowledging, in line with those in the southeast of the state of Mexico (León-Rojas et al. 2020), that excess or insufficient moisture can adversely affect this crop.

Physical capital

The analysis of physical capital focused on machinery ownership and transportation, revealing generally low indices, along with assessing the condition of roads. The sheller machine emerges as the most used machinery. However, only 43% of Maize growers-livestockers FPUs and a mere 4% of the Diversified group own their equipment; the majority opt for renting, thereby heightening external dependence. Similar findings were reported by Sánchez-Morales and Romero-Arenas (2018) among maize farmers in Tlaxcala. This situation aligns with the transportation aspect for moving the harvest, contributing to the sustainability of Maize growers-livestockers.

The Traditional and Diversified groups exhibit better conditions in terms of access roads to their plots of land and the transfer of crops. This advantageous situation allows them to avoid incurring repair costs, in contrast to Maize growers-livestockers, who report a more significant deterioration of the roads.

Integration of indicators

The Diversified group surpasses the Traditional and Maize growers-livestockers groups in terms of sustainability, covering 68% of the sustainability perimeter (Fig. 5). The Diversified FPUs exhibit a more balanced approach, excelling in the capacity to conserve native maize with optimal values in generational continuity. Additionally, they excel in the conservation of natural resources, particularly in terms of traditional knowledge and water, considered a critical aspect. Furthermore, the Diversified group demonstrates adeptness in developing strategies to meet basic needs, with significant values in critical points such as dependence on external resources, profitability, and pluriactivity. In essence, this group boasts a more robust generational relay, ensuring short and medium-term transcendence and the fulfillment of social reproduction needs without compromising the cultivation of native maize. Guillén (2019) underscores the importance of involving younger generations in agricultural processes as a factor influencing sustainability, development, and the enduring presence and consolidation of the rural world in general.

The Traditional FPUs encompass 58%, excelling in establishing robust local relationships, leveraging traditional knowledge, and yielding positive outcomes in terms of diversity and food self-sufficiency. Nevertheless, they are less financially lucrative, more specialized in agriculture, and possess limited physical infrastructure. Elizondo-Salas et al. (2021) propose that reevaluating traditional knowledge is a viable avenue for sustainability. The Maize growers-livestockers group, constituting 52% of the sustainability perimeter, demonstrates positive aspects in profitability, pluriactivity, water, and physical capital. However, it raises concerns regarding sustainability in generational continuity, food diversity, self-sufficiency, reliance on external resources (significantly impacting agrochemical use), and the application of traditional knowledge. Consequently, it stands out as the least sustainable FPUs.

These findings underscore the intricate nature of elements associated with sustainability. Despite estimated sustainability perimeters, each FPU type exhibits strengths and weaknesses in critical areas. Recognizing this is crucial as tailored strategies are necessary for the conservation of FPUs based on their inherent characteristics. Traditional FPUs necessitate technologies suited to their production conditions, less resource-intensive, and enhancing the efficiency and utilization of local resources. The integral role of native maize in their survival strategies establishes a coexistence that could be pivotal for its long-term conservation. Conversely, Maize growers-livestockers are undergoing productive reconfiguration, indicating a need for a shift in their approach to ensure social reproduction and overall system sustainability. Diversified FPUs appear to be the most balanced across indicators. Generally, diversification aligns with sustainability. However, the crux of the matter lies in the continued presence of native maize within this diversified production landscape.

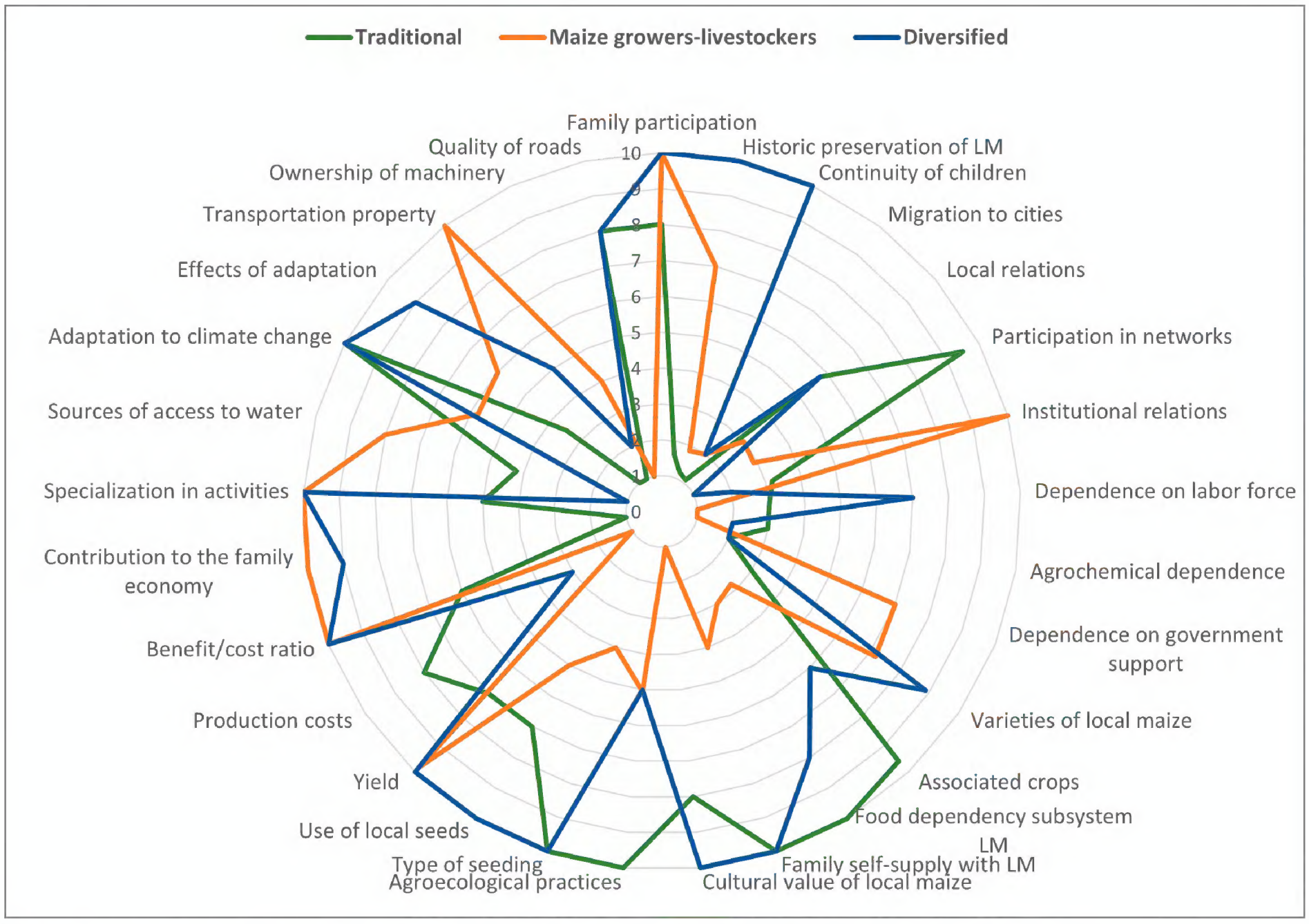

Figure 5. Integral evaluation of sustainability of FPUs growing native maize in Frailesca, Chiapas.

Implications

Based on the analyzed information, the implications in the technological, social, environmental, and economic fields are clearly identified, aligning with the findings of Cortés et al. (2015). They assert that sustainability entails the effective management of natural, human, social, economic, and technological resources to achieve an enhanced quality of life. In this context, social elements emerged as particularly significant for the studied FPUs, with a focus on generational continuity, diversification of socioeconomic or productive activities, and the reinforcement of social capital. Moreover, there exists an intrinsic connection between native maize and the families, forming a holographic and recursive relationship. Conservation is reciprocal: the family preserves native maize, and in turn, native maize facilitates the dynamics of social reproduction within the families. This underscores the intricacy of the holarchies theoretical approach (Castro 2017) yet aligns coherently with the leading evidence suggesting that diversifying income sources and expanding social capital both contribute to the social reproduction of the family. Culturally, native maize is regarded as a significant, viable, and enduring strategy in this regard.

Diversification manifests itself across various scales, whether in the agricultural production system or as a source of income. At both levels, it influences how native maize is cultivated and the decision-making process regarding the retention or abandonment of native varieties. In this instance, two forms of diversification were identified: one occurring within the system itself through polyculture practices, and the other involving a shift towards a maize-livestock system. Some authors conceptualize this diversification logic as the "co-presence" of models (Gasselin et al. 2020), emphasizing its significance for sustainability. Consequently, both forms of diversification carry substantial technological implications, with the maize-livestock system potentially influencing issues such as nutrient flows between soil, maize, stubble, and livestock. This necessitates a discussion on practices like burning, conservation agriculture, or the utilization of stubble as animal feed (Caballero et al. 2017). In this context, the authors contend that a survival rationale, which leads to productive (re)conversion, could potentially result in more sustainable forms of maize-livestock integration (Martínez et al. 2021).

Crucial factors for the sustainability of FPUs are intertwined with external dependencies and their impact on profitability. A comprehensive (holistic) analysis reveals that external dependencies emerge as the most vulnerable variables in terms of sustainability. This is primarily due to inputs constituting the costliest component in native maize cultivation and concurrently serving as the decisive factor influencing its profitability (Martínez-Aguilar 2020b). External requirements introduce an elevated level of uncertainty into farming systems (Samper 2020). A significant reliance on chemical inputs jeopardizes both economic and environmental sustainability (Peralta et al.

2021). In this context, a discernible trend toward an increasing demand is evident, accompanied by diminishing productive and economic responses and subsequent environmental consequences. Some scholars assert that the conservation of agroecosystems and their components, including agrobiodiversity, is fundamentally the linchpin of sustainability (Paleólogos et al. 2021). Consequently, the development of social capital, diversification of the maize system, livestock reconversion, and other related initiatives must establish synergistic, complementary, or substitutive relations to ensure the reproduction of FPUs and their commitment to preserving native maize varieties.

The information presented here holds significance for enhancing public policies, strengthening local development processes, and addressing research needs in terms of sustainability, given the distinct sustainability strategies observed across the three types of FPUs. A common misconception among decision-makers is the advocacy for standardized policy promotion, often overlooking the fact that farmers base their decisions on multiple socio-productive rationalities (Gómez et al. 2023). Traditional FPUs necessitate policies that consider good practices with minimal external input requirements, emphasizing the maximization of local resources. Conversely, maize-livestock FPUs require specific policies that promote action-research on stubble use, recognizing it as an emerging component within the maize-livestock soft system. Ultimately, diversified FPUs appear to strike a more balanced approach in terms of indicators. In general, the encouragement of diversification in FPUs is crucial to ensure the conservation of native maize and maintain its pivotal role in articulating sustainability in the region.

Conclusions

The sustainability of Family Production Units cultivating native maize varieties is not solely dependent on the income derived from maize production. It is also contingent upon the overall system's capacity to leverage family social reproduction. Reproductive strategies grounded in resource allocation, or capitals, give rise to varied forms of nature appropriation, continually reshaped by the sustainability of FPUs cultivating native maize varieties in the Frailesca region. Diversified FPUs prove more sustainable than their Traditional and Maize growers-livestockers counterparts. This is attributed to their better conditions for preserving native maize over time and formulating strategies that concurrently fulfill their diverse needs. Consequently, the sustainability of native maize FPUs is shaped by the different capitals at play and the combinations crafted as part of social reproduction strategies.

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Conflict of interest

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Authors' contributions

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved the final version.

References

Aguilar-Jiménez CE, Galdámez-Gadámez J, Martínez-Aguilar FB, Guevara-Hernández F, Vázquez-Solís H, Llaven-Martínez J (2019) Eficiencia del policutltivo maíz-frijol-calabaza bajo manejo orgánico en la Frailesca, Chiapas, México. Revista Científica Agroecosistemas 7(3): 64–72. https://aes.ucf.edu.cu/index.php/aes

Aguilar-Jiménez C, Tolón-Becerra A, Lastra-Bravo X (2011) Evaluación integrada de la sostenibilidad ambiental, económica y social del cultivo de maíz en Chiapas, México. Revista de La Facultad de Ciencias Agrarias 43(1): 155–174. https://www.redalyc.org/pdf/3828/382837648011.pdf

Aguilar-Vázquez EH, Cadena-Íñiguez P, Guevara-Hernández F, Pinto-Ruíz R, Nahed-Toral J, De la O-Arias MA (2021) Characterization of the backyards , in the families of la Concordia, Chiapas, Characterization of the backyards , in the families of la Concordia, Chiapas, México Caracterização dos traspatios das famílias de la Concordia, Chiapas, México. Brazillan Journal of Animal and Environmental Research 4(3): 4185–4194. https://doi.org/10.34188/bjaerv4n3-107

Arias-Yero I, Guevara-Hernández F, La O-Arias MA, Cadena-Iñiguez P (2022) Caracterización y tipos de familias productoras de maíz local en la Frailesca, Chiapas. CienciaUAT 16(2): 155–171. https://doi.org/10.29059/cienciauat.v16i2.1525

Arias-Yero I, Guevara-Hernández F, La O-Arias, MA, Villegas-Chadez R (2023) Caracterización de capitales tangibles en unidades de producción familiar con maíces locales en Chiapas, México. Universidad y Sociedad 15(6): 446–455. https://rus.ucf.edu.cu/index.php/rus/article/view/4163%20Consultado%2006/Ene/2024

Astier M, Masera O, Galván-Miyoshi Y (2008) Evaluación de la Sustentabilidad. Un enfoque Dinámico y multidimensional. In Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki.

Barrios-García G, D´hers V, Veiguela N, Khoury M (2020) Metabolismo social. Revista Iberoamericana de Economía Ecológica 33(1): 99–111. https://raco.cat/index.php/Revibec/article/view/381034

Bellon MR, Adato M, Becerril J, Mindek D (2006) Poor farmers' perceived benefits from different types of maize germplasm: The case of creolization in lowland tropical Mexico World Development 34(1): 113–129. https://doi.org/10.1016/j.worlddev.2005.05.012

Bellon RM, Barrientos-Priego AF, Colunga-GarcíaMarín P, Perales H, Reyes-Agüero JA, Rosales-Serna R, Zizumbo-Villareal D (2009) Diversidad y conservación de recursos genéticos en plantas cultivadas. Capital Natural de México, 2(April 2015): 355–382.

Blandi M, Sarandón S, Flores C, Veiga I (2015) Evaluación de la sustentabilidad de la incorporación del cultivo bajo cubierta en la horticultura platense. Revista de La Facultad de Agronomía La Plata 114(2): 251–264. http://sedici.unlp.edu.ar/handle/10915/51351

Bourdieu P (1979) Los tres estados del capital cultural. Sociológica 5(2): 11–17. http://www.sociologicamexico.azc.uam.mx/index.php/Sociologica/article/view/1043

Bourdieu P (2002) Estrategias de reproducción y modos de dominación. Colección Pedagógica Universitaria 37–38: 1–21. https://www.uv.mx/cpue/coleccion/N_3738/C%20Bourdieu%20estrategias%20dominacion.pdf

Bourdieu P (2011) Las estrategias de la reproducción social (L. Padilla-López (ed.); Primera). Siglo Veintiuno Editores S. A. https://sociologiac.net/2013/10/28/descarga-del-dia-las-estrategias-de-la-reproduccion-social-pierre-bourdieu/

Caballero Salinas JC, Moreno Reséndez A, Reyes Carrillo JL, García Valdez JS, López Báez W, Jiménez Trujillo JA (2017) Competencia del uso del rastrojo de maíz en sistemas agropecuarios mixtos en Chiapas. Revista mexicana de ciencias agrícolas 8(1): 91–104. https://doi.org/10.29312/remexca.v8i1.74

Cadena-Íñiguez P (2004) Actores, estrategias y dinámicas de organización en el agro de la Frailesca, Chiapas. Colegio de Postgraduados. Institución de enseñanza e Investigación en Ciencias Agrícolas. https://chapingo.orex.es/cgi-bin/koha/opac-detail.pl?biblionumber=90371&shelfbrowse_itemnumber=173464

Castro-Díaz R (2017) Epistemología y pragmatismo en el análisis de los sistemas complejos. Revista Latinoamericana de Metodología de las Ciencias Sociales 7(2): e026. https://doi.org/10.24215/18537863e026

Cortés Mura HG, Peña Reyes JI (2015) De la sostenibilidad a la sustentabilidad. Modelo de desarrollo sustentable para su implementación en políticas y proyectos. Revista EAN (78): 40–55. https://doi.org/10.21158/01208160.n78.2015.1189

Cuevas-Coeto A, Vera-Castillo YB, Cuevas-Sánchez JA (2019) Resiliencia y sostenibilidad de agroecosistemas tradicionales de México: Totonacapan. Revista Mexicana de Ciencias Agrícolas 10(1): 165–175. https://doi.org/10.29312/remexca.v10i1.1789

Delgado-Ruiz F, Guevara-Hernández F, Acosta-Roca R (2018) Criterios campesinos para la selección de maíz (*Zea mays* L.) en Villaflores y Villa Corzo, Chiapas, México. CienciaUAT 13(1): 123. https://doi.org/10.29059/cienciauat.v13i1.985

Díaz-José J, Guevara-Hernández F, Rodríguez-Laramendi L, Nahed-Toral J, Pinto-Ruiz R, Ley-De Coss A, Aguirre-López J (2018) Vulnerability, innovation y social resilience en the maize (*Zea mays* L.) Production: The case of the Conservation Tillage Club of Chiapas, Mexico. Tropical and Subtropical Agroecosystems 21: 399–408. https://doi.org/10.56369/tsaes.2440

Easdale MH, López DR, Aguiar MR (2018) Tensiones entre conservación de ecosistemas y desarrollo territorial: hacia un abordaje socioecológico en las Ciencias Agropecuarias. Cuadernos de Desarrollo Rural 15(81): 1–19. https://doi.org/10.11144/Javeriana.cdr15-81.tced

Elizondo-Salas C, Jimeno-Sevilla D, Díaz-José J (2021) Consumo de insectos y plantas silvestres comestibles, una experiencia de educación ambiental con jóvenes indígenas de la sierra de Zongolica, Veracruz. In Transición para el desarrollo sustentable, Serie Dialogando lo Ambiental (Issue June): 138–154.

Fletes-Ocón H (2017) Prácticas de los pequeños productores por seguridad y soberanía alimentaria en el Sur de México. XXXI Congreso ALAS. https://www.easyplanners.net/alas2017/opc/tl/3595_hector_fletes_ocon.pdf

Fletes-Ocón H, Rangel F, Oliva-Velas A, Ocampo-Guzmán G (2014) Revalorizar a los pequeños prodcutores. Contribuciones y rsistencias en una región agroexportadora de Chiapas. In: Fletes-Ocón H, Macías-Macías A, Madera-Pacheco JA (Eds) El papel de los pequeños productores en la agricultura y alimentación. La experiencia desde tres regiones agrícolas en México (Primera, 93–151). Plaza y Valdés S.A de C.V. https://ejournal.poltektegal.ac.id/index.php/siklus/article/view/298%0Ahttp://repositorio.unan.edu.ni/2986/1/5624.pdf%0Ahttp://dx.doi.org/10.1016/j.jana.2015.10.005%0Ahttp://www.biomedcentral.com/1471-2458/12/58%0Ahttp://ovidsp.ovid.com/ovidweb.cgi?T=JS&P

Gasselin P, Lardon S, Cerdan C, Loudiyi S, Sautier D (2020) La convivencia de modelos agrícolas y alimentarios a escala territorial: un marco analítico para una agenda de investigación. Rev Agric Food Environ Stud 101: 339–361. https://doi.org/10.1007/s41130-020-00119-7

Gobierno del estado de Chiapas (2014) Programa regional de desarrollo 2013–2018. Región VI Frailesca. http://www.ped.chiapas.gob.mx/ped/wp-content/uploads/ProgReg/2013-2018/2013_PRD_6_Frailesca.pdf

Gómez CA (2023) ¿Agricultura familiar vs. agronegocios? acerca de racionalidad y estructura de las relaciones de producción en los espacios sociales agrarios. Alter-Nativa (9): 91–111 https://revistas.unc.edu.ar/index.php/alter-nativa/article/view/40951

Guevara-Hernández F (2007) ¿Y después qué?: action-research and ethnography on governance, actors and development in Southern Mexico. Technology and Agrarian Development Group. Department of Social Sciences. Wageningen University and Research Centre. Wageningen, The Netherlands, 223 pp. https://edepot.wur.nl/43322

Guevara-Hernández F, Mariaca-Méndez R (2023) Importancia actual de los maíces locales (*Zea mays* L.): aportes y reflexiones etnobotánicas desde Chiapas, México. Universidad y Sociedad 15(6): 438–445. https://rus.ucf.edu.cu/index.php/rus/article/view/4162Consultado:06/Ene/2024

Guevara-Hernández F, McCune NM, Gómez-Castro H, Pinto-Ruiz R, Medina-Jonapá FJ, Hernández-López A, Tejeda-Cruz C (2011) Conflicting regulatory systems for Natural Resources Management in Southern Mexico: An ethnographic case study. International Journal of Technology and Development Studies 1(2): 30–62.

Guevara-Hernández F, Rodríguez-Larramendi LA, Hernández-Ramos MA, Fonseca-Flores M de los Á (2015) Eficiencia energética y económica del cultivo de maíz en la zona de amortiguamiento de la Reserva de la Biosfera "La Sepultura", Chiapas, México. Revista Mexicana de Ciencias Agrícolas 6(8): 1929–1941. https://doi.org/10.29312/remexca.v6i8.530

Guevara-Hernández F, Rodríguez-Larramendi LA, Díaz-José J, Pinto-Ruiz R (2018a) Actores y estrategias de la innovación tecnológica en la producción de maíz en Chiapas, México. Revista de La Facultad de Agronomía Luz 35(2): 223–247. https://produccioncientificaluz.org/index.php/agronomia/article/view/27273

Guevara-Hernández F, Delgado-Ruiz F, La O-Arias MA, Rodríguez-Larramendi LA, Ortíz-Pérez R, Delgado-Ruiz JA, Venegas-Venegas JA, Pinto-Ruiz R (2018b) Análisis comparativo energético-económico del agroecosistema maíz bajo prácticas convencionales y de conservación en la región Frailesca, Chiapas, México. Revista de La Facultad de Agronomía Luz 35(3): 343–364.

Guevara-Hernández F, Hernández-Ramos MA, Basterrechea-Bermejo JL, Pinto-Ruiz R, Venegas-Venegas JA, Rodríguez-Larramendi LA, Cadena-Iñiguez P (2019a) Maíces locales; una contextualización de identidad tradicional. Revista FCA Uncuyo 51(1): 369–381. https://revistas.uncu.edu.ar/ojs3/index.php/RFCA/article/view/2457

Guevara-Hernández F, Hernández-Ramos MA, Pinto-Ruiz R, Arias-Yero I, Rodríguez-Larramendi LA, Medina-Sansón L, Rodríguez-Rodríguez S (2019b) Oportunidades para la innovación de sistemas tradicionales de producción agropecuaria: un análisis socioantropológico retrospectivo. CIENCIA Ergo Sum 26(1): 1–18. https://doi.org/10.30878/ces.v26n1a1

Guevara-Hernández F, Hernández-Ramos MA, Basterrechea-Bermejo JL, Fonseca-Flores M de los Á, Delgado-Ruiz F, Ocaña-Grajales M de J, Acosta-Roca R (2020) Riqueza de maíces locales (*Zea mays* L.) en la Frailesca, Chiapas, México: un estudio etnobotánico. Revista. Facultad Agronomía Luz 37(3): 223–243. https://www.produccioncientificaluz.org/index.php/agronomia/article/view/32660

Guevara-Hernández F, Hernández-Ramos MA, Ortíz-Pérez RH, Acosta-Roca R, Rosabal-Ayan L, La O-Arias MA, Pinto-Ruiz R, Martínez-Aguilar FB, Reyes-Sosa MB (2021) Maíces locales de La Frailesca chiapaneca: diversidad, usos múltiples y distribución. Ediciones INCA y Unidad de Divulgación Científica-UNACH. San José de las Lajas, Mayabeque, Cuba, 121 pp. https://isbnmexico.indautor.cerlalc.org/catalogo.php?mode=detalle&nt=349818

Guillén J (2019) La experiencia de Nochari en Granada. In: Vivas E, Murillo L, López N (Eds) Agroecología, Herramienta para la transformación. Friedrichebert Stiftum. www.fesamericacentral.org

Gutiérrez-Cedillo JG, Aguilera-Gómez LI, González-Esquivel CE (2008) Agroecología y sustentabilidad. Revista de Ciencias Sociales Convergencia 46: 51–87. https://convergencia.uaemex.mx/article/view/1341

Hellin J, Bellon M (2007) Manejo de semillas y diversidad del maíz. LEISA Revista de Agroecología, 9–11. https://www.leisa-al.org/web/images/stories/revistapdf/vol23n2.pdf

Hernández-Ramos MA, Guevara-Hernández F, Basterrechea-Bermejo JL, Coutiño-Estrada B, La O-Arias MA, Pinto-Ruiz R (2020) Diversity and Conservation of Local Maize from La Frailesca, Chiapas, Mexico. Revista Fitotecnia Mexicana 43(4): 471–480. https://doi.org/10.35196/rfm.2020.4.471

León-Rojas GI, Rodríguez-Soto C, Padilla-Loredo S (2020) La conservación in situ del frijol criollo: construyendo soberanía alimentaria en el sureste del estado de México. Revista CoPaLa Construyendo Paz Latinoamericana 5(9): 125–141. https://doi.org/10.35600/25008870.2020.9.00159

López-González JL, Damián-Huato MÁ, Álvarez-Gaxiola JF, Méndez-Espinosa JA (2018) El diálogo de saberes en el manejo del maíz en Calpan, Puebla, México. Regiones y Desarrollo Sutentable 34: 27–47. http://coltlax.edu.mx/openj/index.php/ReyDS/article/view/15

López-Torres BJ, Rendón-Medel R, Camacho Villa TC (2017) La comercialización de los maíces de especialidad en México: condiciones actuales y perspectivas. Revista Mexicana de Ciencias Agrícolas 15: 3075–3088. https://doi.org/10.29312/remexca.v0i15.427

Martínez-Aguilar FB, Guevara-Hernández F, La O-Arias MA, Aguilar-Jiménez CE, Rodríguez-Larramendi LA, Pinto-Ruiz R (2021) Tipificación socio-agronómica y energética de productores de maíz en la región Frailesca, Chiapas, México. Rev Fac Agron Luz 38(1): 176–198. https://doi.org/10.47280/RevFacAgron(LUZ).v38.n1.09

Martínez-Aguilar FB, Guevara-Hernández F, Aguilar-Jiménez CE, Rodríguez-Larramendi LA, Reyes-Sosa MB, LaO-Arias MA (2020a) Caracterización físico-química y biológica del suelo cultivado con maíz en sistemas convencional, agroecológico y mixto en la Frailesca, Chiapas. Terra Latinoamericana 38(4): 871–881. https://www.redalyc.org/articulo.oa?id=57366267015

Martínez-Aguilar FB, Guevara-Hernández F, Rodríguez-Larramendi LA, La O-Arias MA, Pinto-Ruiz R, Aguilar-Jiménez CE (2020b) Caracterización de productores de maíz e indicadores de sustentabilidad en Chiapas. Revista Mexicana de Ciencias Agrícolas 11(5): 1031–1042. https://doi.org/10.29312/remexca.v11i5.2189

Masera O, Astier M, López-Ridaura S, Galván-Miyoshi Y, Ortiz-Ávila T, García-Barrios L, García-Barrios R, González C, Speelman E (2008) El proyecto de evaluación de sustentabilidad MESMIS. In: Astier M, Masera O, Galván Y (Eds) Zhurnal Eksperimental'noi i Teoretich-eskoi Fiziki, Primera, 202 pp. [SEAE / CIGA / ECOSUR / CIEco / UNAM / GIRA / Mundiprensa / Fundación Instituto de Agricultura Ecológica y Sustentable]

Maza N, Sarandón SJ (2015) Evaluación de la sustentabilidad del sistema de producción de pimiento bajo cubierta en Tucumán, Argentina. Congreso Latinoamenricano de Agroecología, 1–6. http://sedici.unlp.edu.ar/handle/10915/58475

Orozco-Hernández M, García-Fajardo B, Álvarez-Arteaga G, Mireles-Lezama P (2017) Tendencias del sector agrícola, Estado de México. Quivera 1(19): 99–121. https://www.redalyc.org/pdf/401/40153531006.pdf

Paleólogos MF, Iermanó MJ, Blandi ML, Sarandón SJ (2021) Las relaciones ecológicas: un aspecto central en el rediseño de agroecosistemas sustentables, a partir de la Agroecología. Redes 22(2): 92–115.

Perales H (2009) Maíz, riqueza de México. Ciencias 92–93: 46–55. http://redalyc.uaemex.mx/src/inicio/ArtPdfRed.jsp?iCve=64412119008

Peralta YAA, Ortega ER, Lagos GAB (2021) Estudio econométrico sobre el rendimiento productivo de granos básicos en Nicaragua (arroz, maíz y frijol), 2007–2017. Revista de Investigación Sigma 8(02): 31–41.

Picazzo-Palencia E, Flores-Segovia MA, Cruz-Maldonado ME De (2018) Análisis regional de la esperanza de vida al nacer en México, por medio del método de regresión. Revista Salud Pública 20(6): 725–729. https://doi.org/10.15446/rsap.v20n6.35806

Pizaña-Vidal HA, Fletes-Ocón HB, González-Cabañas AA (2019) Agronegocios y campesinos maiceros en la Frailesca: vulnerabilidad y resistencias. Eutopía Revista de Desarrollo Económico Territorial 15: 11–31. https://doi.org/10.17141/eutopia.15.2019.3865

Salazar-Barrientos L, Magaña-Magaña M (2016) Aportación de la milpa y traspatio a la autosuficiencia alimentaria en comunidades mayas de Yucatán. Estudios Sociales 24(47): 182–203. https://www.ciad.mx/estudiosociales/index.php/es/article/view/295/214

Samper Kutschbach M (2020) Contribuciones de los agroecosistemas campesinos y sistemas territoriales de agricultura familiar al desarrollo de los territorios rurales y a la seguridad alimentaria: conceptos medulares y cuestiones actuales. Enfoque Rural 1(1): 58–80. https://enfoquerural.uaemex.mx/article/view/15472

Sánchez-Gómez J, Rendón-Medel R, Cuevas-Reyes V, Díaz-José J (2021) El papel de los actores institucionales como fuente de innovación para los productores de maíz en México. Ciencia y Tecnología Agropecuaria 22(2). https://doi.org/10.21930/rcta.vol22_num2_art:1632

Sánchez-Morales P, Romero-Arenas O (2018) Evaluación de la sustentabilidad del sistema milpa en el estado de Tlaxcala, México. Revista de El Colegio de San Luis 8(15): 107. https://doi.org/10.21696/rcsl8152018745

SIAP [Servicio de Información Agroalimentaria y Pesquera] (2019, 2020) Anuario estadístico de la producción agrícola en México. https://nube.siap.gob.mx/cierreagricola/

Speelman E, Astier M, Galván Y (2008) Sistematización y análisis de los estudios de caso MESMIS: lecciones para el futuro. In: Astier M, Masera O, Galván-Miyoshi Y (Eds) Evaluación de susentabilidad. Un enfoque dinámico y multidimensional.

Toledo VM (2008) Metabolismos rurales: hacia una teoría económico-ecológica de la apropiación de la naturaleza. Revista Iberoamericana de Economía Ecológica 7: 1–26. https://core.ac.uk/download/pdf/6249253.pdf

Toledo VM (2013) El metabolismo social: una nueva teoría socioecológica. Revista relaciones: 136: 41–71. https://doi.org/10.24901/rehs.v34i136.163

Uzcanga-Pérez NG, Chanatásig-Vaca CI, Cano-González A (2020) Sustentabilidad socioeconómica y ambiental de los sistemas de producción de maíz de temporal. Revista Mexicana de Ciencias Agrícolas 11(5): 993–1004. https://doi.org/10.29312/remexca.v11i5.2117

Vázquez-González LB, Parra-Vázquez MR, Gracia MA (2018) Transformaciones en la agricultura de los mayas peninsulares: Un contraste de los casos de Kampocolché y Xohuayán. Mundo Agrario 19(41): e084. https://doi.org/10.24215/15155994e084

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